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⑨ FINAL REPORT No. 788

⑥ GROUND BASED RAINDROP SPECTROMETER

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February 1962

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by

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GROUND BASED RAINDROP SPECTROMETER

FINAL REPORT No. 788

February 1962

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## ACKNOWLEDGEMENTS

## ABSTRACT

A novel ground-based Raindrop Spectrometer is described and its operating principles explained. The instrument is designed to count and size automatically all raindrops falling freely through an optically defined sampling area of 32 cm$^2$. All drops larger than 0.2 mm in diameter are counted and assigned to the appropriate one of 13 size intervals, the last interval being drops larger than 4.6 mm.

The running total count of drops in each size interval is accumulated in an electronic memory for a time interval which can be preset to any duration from 5 seconds to 3 minutes. Then the stored counts are read out automatically and recorded on a paper tape punch in seconds, after which the memory clears and data accumulation begins again. The instrument can store up to 10,000 counts in each of the thirteen size intervals during each data collection period. From the record, the following information can be derived: raindrop size spectra as a function of time, average volume drop radius, total rainfall or rainfall rate.

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# GROUND BASED RAINDROP SPECTROMETER

## I. INTRODUCTION

This report is being submitted in partial fulfillment of Contract DA36-039-SC-84970, 30 June 1960. The Raindrop Spectrometer which was developed and constructed under this contract was delivered to U.S.A.S.R.D.L. on 1 December 1961. This report is primarily a description of the equipment and a discussion of its operating principles.

### I.1 Requirements (SCL-5777, 18 February 1960)

1. The (raindrop) spectrometer shall be capable of determining the number and size of all particles of 200 microns diameter and larger. The minimum acceptable counting rate shall be 10 drops per $cm^2$ per second.

2. It shall be possible to obtain the droplet size distribution, the average volume radius, and the rate of rain. The original data shall come either integrated over pre-selected time intervals (one to several minutes) or continuously.

3. As a general guideline in accuracy, it shall be possible to determine the mass from drop radius within an accuracy of $\pm$ 15 percent.

4. The instrument shall be thoroughly calibrated, using laboratory produced drops of known radius. The calibration shall not be dependent on the angle of fall of the drop.

5. Counting units shall give a running total of the number of drops in each size range, with the print-outs of the total in each unit at the end of the pre-selected time interval.

6. The rate of rain (total water content) shall either be measured separately or electronically evaluated from the droplet data. In either case it shall be printed at the end of each time interval. The desired accuracy shall be $\pm$ 15 percent.

I.2 General Description

The Raindrop Spectrometer is an optical-electronic instrument which counts and sizes raindrops automatically. The instrument's sensing head, located outdoors, collects data on each and every raindrop falling freely through an optically defined sampling area of approximately 32 $cm^2$. The instrument assigns all drops larger than 0.2 mm in diameter to the appropriate one of thirteen size intervals, the last interval being all drops larger than 4.6 mm in diameter.

The running total count of drops in each size interval is accumulated in an electronic memory for a predetermined time interval and then the stored count is read out and recorded on a paper tape punch, after which the memory is cleared and data accumulation begins again. The data collection period can be preset to any duration from five seconds to three minutes, while the data readout and recording time is fixed at 3.8 seconds. The system can store as many as 10,000 counts for each of the thirteen size intervals during each data collection period.

The recorded data is in the form of a cumulative size spectrum where the number of drops greater than each of thirteen graduated sizes ranging from 0.2 mm to 4.6 mm are tabulated. An actual size spectrum is easily obtained from the record by subtracting the count accumulated in the thirteenth size interval, or channel, from that of the twelfth and so on. In this way, the true count in each size interval is obtained rather than the cumulative count, i.e., all drops larger than a particular size. It is expected that the analysis of the data will be carried out by means of a paper tape reader and a computer which could easily carry out the subtractions and present the size spectra as functions of time. A computer can also easily compute average volume radius, total rainfall or rainfall rate from the size spectra.

The Raindrop Spectrometer includes several pieces of equipment. A collimated light source projects horizontally an intense, rectangular beam of uniform intensity. An optical telescope of unit magnification, placed at an angle to the light beam and in the same horizontal plane, "sees" all the raindrops falling through a section of the beam. The sample region is thus defined by the optical intersection of the telescope's field of view and the light beam. The telescope has a telecentric stop which causes it to accept only those light rays which are close to paraxial, so that its angular field of view is close to zero degrees. This has the desirable effect of giving great depth of field so that all drops in the sample region are in sharp focus and also prevents ambient illumination from having any effect on the operation of the system.

The drop is imaged on a grid (5 cm. wide) consisting of fourteen horizontal slots or windows separated by opaque gaps. Each of the windows is the end of a long flat Lucite strip which pipes the light to a photomultiplier tube at its opposite end. Each window is separated from the next by a gap. The gap between the bottom window and the next higher is set to match the image size of a 0.2 mm drop, the gap between the second and third is set for 0.26 mm, and so on up through the series. (See Figure 13,000).

When a raindrop falls through the sample volume, its

image traverses the set of windows from bottom to top generating a series of voltage pulses in the associated photomultipliers. As long as the drop image is larger than the gap between two adjacent windows, it generates signal voltage pulses in the adjacent photomultipliers which overlap in real time. However, when the image reaches a gap that is as large or larger than itself, the signal pulses in the two adjacent photomultipliers cannot overlap in time. Thus it can be sized by means of coincidence circuits, and a count sent to the memory unit. The raindrop itself is not interfered with either before or after it is measured. (See Figure 1).

The sizing grid, photomultipliers and associated sizing circuits are housed in a weatherproof chassis attached to the optical telescope. From this chassis, the signal pulses indicating count in each size channel are carried over transmission lines to a nearby rack assembly which is indoors. The rack contains the counters, programing switches, power supplies and timing circuits. Data are read out of the memory-counters and recorded on a tape punch recorder adjacent to the rack at periodic intervals. A standard tipping-bucket rain gauge is placed near the sensor in order to obtain an independent measurement of total rainfall. The number of tips measured are counted by a single decade counter in the rack assembly and recorded on the tape punch as channel 14.

## II. SYSTEM OPERATION

### II.1 Principles of Operation

Drops falling freely through a brightly illuminated
sampling region are viewed against a black background by
an optical system which images the droplets on a planar
grid or array of horizontal slits. These narrow slits or
windows, all of the same size, are separated by opaque gaps
of gradually increasing height. The array of slits thus
consists of a series of uniform rectangular windows, narrow
in the vertical direction but quite wide horizontally (0.025x5cm.).
These are arranged one above another and separated by
distances which progressively increase as the drop image
traverses the grid from bottom to top.

All drops within the sampling region form bright
images which traverse the windows in succession as the drop
falls directly through the field. As a drop image crosses
slit 1, a photosensitive detector (photomultiplier No. 1)
which views all of the light collected by window 1, will be
actuated. Subsequently, the edge of the drop image will pass
into slit 2, and similarly actuate photosensitive device 2.
If the drop image diameter is larger than the space between
slits 1 and 2, then both detectors, 1 and 2 will be on simul-
taneously for some short period of time. By feeding the out-
puts of detectors 1 and 2 into a coincidence detector, an
output signal can thereby be derived during the time when a
drop simultaneously overlaps slits 1 and 2. The implication

of such a standardized output pulse is that the drop is larger than the dimension of the gap between slits 1 and 2.

Similarly, this process is repeated for slits 2 and 3 and so on until finally the drop image crosses slit n-1 without simultaneously overlapping slit n because its diameter is less than the space between n-1 and n. (See Figure 1).

If now, each coincidence detector drives an electronic counter, then each drop will activate all counters from No. 1 (slits 1 and 2) to No. n-1 and fail to activate all counters after No. n-1.

Thus, the counting and sizing system can size droplets into any reasonable number of size intervals with interval width determined only by the choice of how many windows one cares to employ. Although the smallest size interval counter, No. 1, records not only droplets lying within that interval (par ex., 200 to 260 microns) but also all larger droplets, this is not objectionable since one has only to subtract from the No. 1 counter the total count of the No. 2 counter to get the actual count in interval No. 1.

The total count accumulated in each channel is stored in electronic decade counters for an interval of time determined by the operator. At the end of this preset interval, all counters are sequentially scanned by means of rotary switches which automatically read out the accumulated counts stored

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Figure 1.  DROP SIZING PRINCIPLE

Windows    Direction    Photosensitive Coincidence  Counters
           of fall      detectors      detectors

Drop history

A)  Crosses window No. 1

B)  Overlaps windows No. 1 and 2
    Registers counter No. 1

C)  Crosses window No. 2

D)  Fails to overlap
    windows No. 2 and 3

Punch tape
recorder

Timer

Sequential
readout switch

Photodetector
waveforms
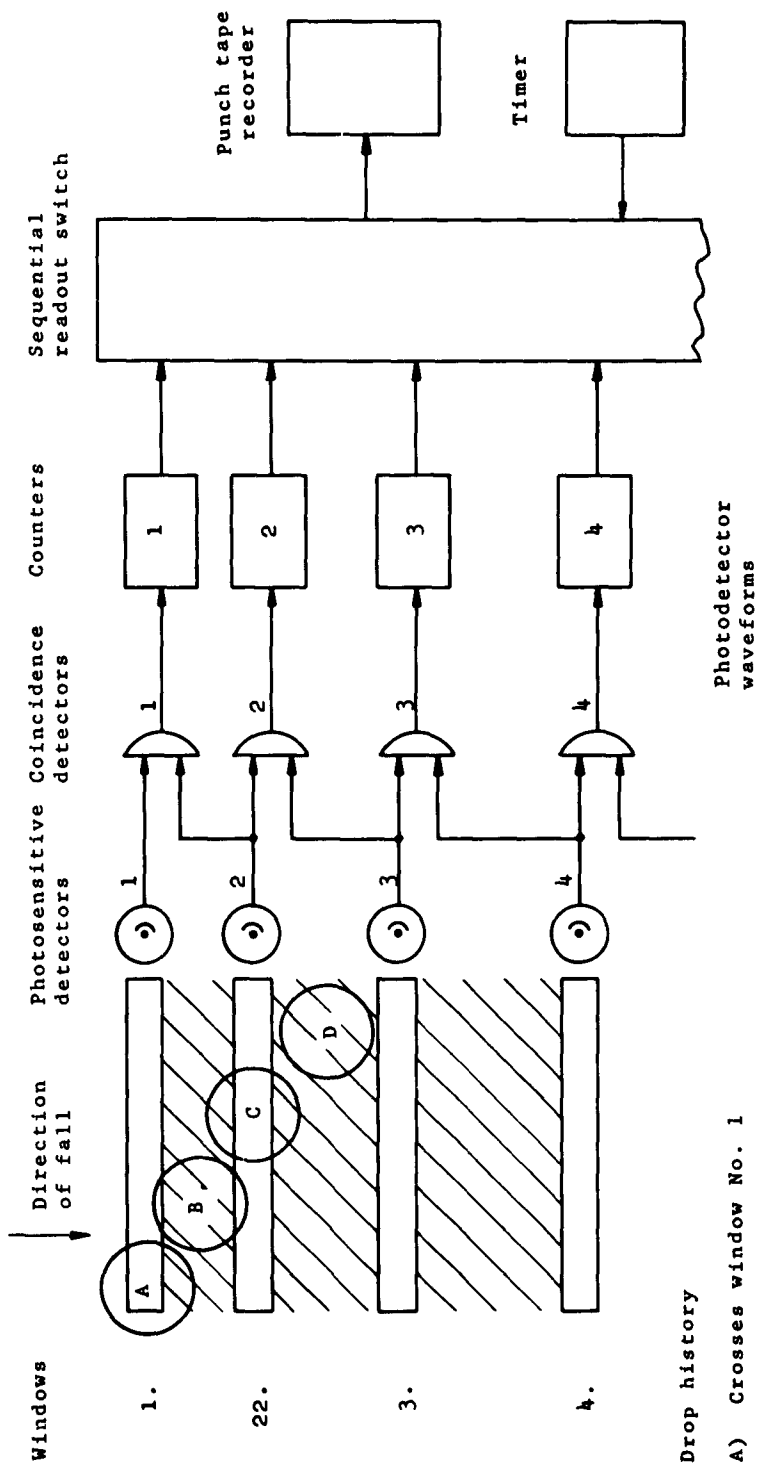
in the counters and transmit them in sequence to a punch
tape recorder. In this manner, the cumulative size spectrum
data recorded during a fixed interval (one minute, for ex-
ammple) is transcribed onto a punch tape during the 3.8
second readout. Thereupon all counters are reset to zero
and the accumulation of new data begins immediately.

There is also an automatic rain detector mounted on
the collimated light source which starts the Spectrometer
operating as soon as rainfall commences and shuts it off
some time after the cessation of rainfall. The rain de-
tector consists of a simple pair of contacts exposed to the
rain so as to short out.when wet. It can be used by putting
the Raindrop Spectrometer in a "standby" condition. However,
the automatic rain detector can be bypassed by means of a
"Manual" on-off switch.

## II.2  System Advantages

Sizing raindrops accurately and reliably has been an
unsolved problem of long standing. Efforts to devise a satis-
factory technique range from the measurement of splash areas
on slate, filter paper, or nylon mesh to optical or photo-
graphic techniques. To date, none of the many techniques
used are truly adequate. Difficulties include biased
sampling, interference with the natural drop size distri-
bution by the device itself, poor resolution and accuracy at

either or both ends of the drop size spectrum, insufficient sample for statistically valid data, and tedious data reduction requirements.

Two major classes of optical techniques have been employed: 1) Instruments which form actual images of the drops for immediate sizing or photographic recording. 2) Instruments which involve the observation of some portion of the scattered light from an illuminated drop and the measurement of its intensity as a measure of size.

Those instruments which form actual images of droplets for sizing purposes usually have employed photographic recording of either stationary droplet image or streaks produced by falling droplets. The photographic record is subsequently examined or scanned automatically to obtain droplet size data. Automatic scanning systems have been developed using either flying spot or slit scan techniques to size photographic images.

Another approach that has been suggested is to use a vidicon camera tube to record temporarily the streak images of falling droplets which can then be sized automatically by an electronic flying spot scan on the face of the tube to measure the chord of the droplets by crossing the streak images. Such a television technique does offer large amounts of data in a short time but suffers from complexity and inadequate resolution (smallest size drop 0.25 mm). The photo-

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graphic approaches are far from being ideal in that they do not offer automaticity and require elaborate scanning devices for subsequent analysis.

The second class of optical techniques which has been employed is the use of scattered light from illuminated drops. Usually the intensity of the light scattered into a restricted solid angle is measured and related to drop size. Although this approach is a classical one, particuarly for aerosols composed of very small droplets, it suffers from severe disadvantages.

The accuracy achieved has been generally low for several reasons. Calibration can change with component aging, drifts in photodetector sensitivity or light source intensity. Drops are sized by means of signal pulse amplitude discrimination - inherently less accurate and reliable than pulse coincidence techniques such as described herein. Sampling volume must be kept small to reduce the chance of observing more than one drop at a time. Finally, the technique's accuracy depends completely on the sphericity of the drops - a condition never exactly met by raindrops, whose shape oscillates slightly from spherical. For drops even slightly out of round, the angular scattering function varies drastically and thus strongly affects instrument calibration.

The advantages of the slit sizing optical system used in the Automatic Raindrop Size Spectrometer herein described are many. A large sampling volume may be employed which is

essentially out in the open so as to prevent local turbulence from biasing results. Observation is continuous since the counters give running total count. Sample data is taken periodically by printing out the counter readings at intervals. The accuracy of sizing is high since the array of slits and gaps is fabricated to high tolerances.

More than one drop can be tolerated within the sampling region at one time since the likelihood of two drops being at the same horizontal level in the sampling region simultaneously is slight. Reasonably small components of lateral velocity as droplets pass through the field of view will not affect the device's ability to measure size accurately. Note that the drops which fall vertically will cross all fourteen windows in the array, but if they fall at an angle to the vertical, then some drop images will enter or leave the sizing grid at the sides. This, of course, leads to an incorrect size assignment for those drops. But, it can be shown that just as many drops of any particular size will enter the side at a particular level as will leave it at the same level. Therefore, with sufficient numbers of drops collected, such errors will exactly average out. The 1 cm overall grid stack height (small in comparison to a 5 cm width) tends to further minimize slant trajectory problems.

As a consequence of the go-no-go coincidence technique used to size the drops, the system is relatively insensitive to the amplitude of the signals generated by the drop images.

Therefore, light levels are not at all critical and sizing is much less ambiguous than with the amplitude discrimination techniques used in light scattering instruments.

The accurate measurement of drop sizes by these means requires that the drops be spherical in shape. However, it is known that falling raindrops tend to oscillate in shape, becoming ellipsoidal at the limits of oscillation. The frequency of these oscillations decrease rapidly as drop size increases and the amplitude increases with size. Stroboscopic photographs which have been made of freely falling drops have shown an almost equal tendency for the major axis to be vertical or horizontal in smaller sizes ($\approx$ 1 mm dia.). In other words, oscillating drops will, with almost equal probability, be elongated slightly vertically or horizontally at any instant. The vertical to horizontal axis ratio of drops up to 3 mm in size is greater than 0.92[*], thus oscillation effects are of small importance in the 0 - 3 mm diameter size range.

III.   ELECTRONIC SYSTEM

The electronic sections of the Spectrometer consist of two major units, the sensor chassis and the data storage rack. The data from the output of the sensor chassis is fed into the rack assembly for processing and storage, and finally goes into the punch tape recorder.

III.1  Sensor Chassis

Part of Figure 2 shows the block diagram of the sensor chassis with its fourteen identical window channels.

[*]Jones, Douglas M.A., "The Shape of Raindrops, Jour. of Met. Vol.16, p. 504.
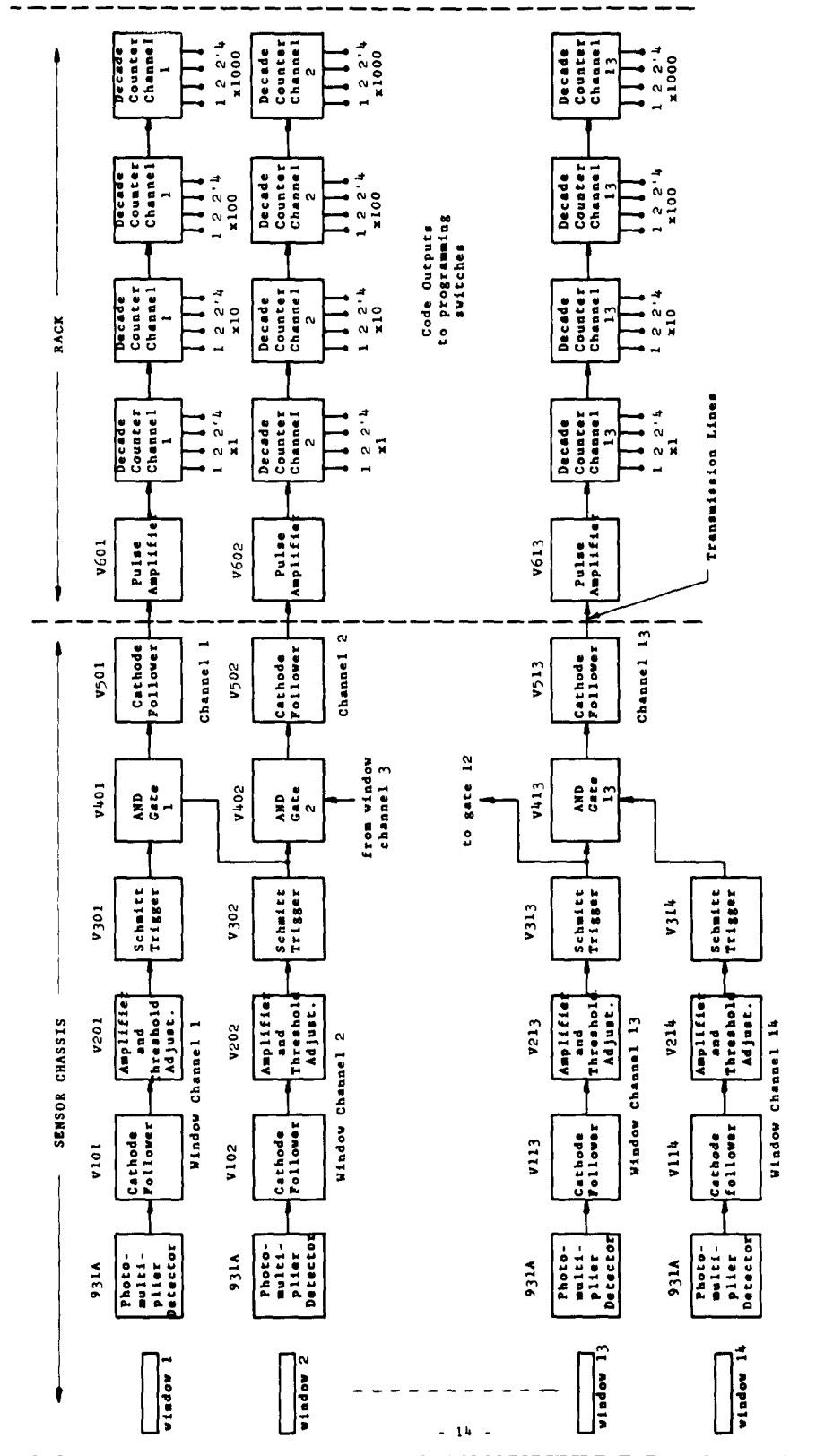
Figure 2.  RAINDROP SIGNAL SIZING and COUNTING CIRCUITS

BLOCK DIAGRAM

The light signals from illuminated raindrop images are
relayed by the Lucite window-light pipes to the photo-
cathode of their associated photomultiplier (931-A). Each
raindrop thus produces a pulse of photoelectric current in
each photomultiplier which appears at the anode as an ampli-
fied negative polarity current pulse. Tracing through the
block diagram of window channel No. 1, (Figure 2), the signal
pulse is fed to a cathode follower buffer stage (V101) whose
high input resistance and low input capacitance serve as the
anode load for the photomultiplier. These cathode followers
are located right at the photomultiplier sockets and their
low output impedance prevents any noise pickup or inter-
channel crosstalk.

The negative signal taken from the output of the
cathode follower is amplified and inverted by the amplifier
and threshold adjustment stage (V201). This stage provides
sufficient voltage amplification for signals generated by
the smallest measured droplets and it also provides a D.C.
reference voltage from which all signals start. This D.C.
reference voltage is adjusted to + 15 volts for all window
channels. Thus the D.C. voltage amplitude at the output of
this stage is the superposition of two voltages - the D.C.
reference voltage and pulse signal amplitude of a particular
droplet.

The output of this stage is D.C. coupled to the next
stage - a Schmitt trigger circuit (V401). This stage
is triggered by all input signals whose voltage amplitudes

exceed the threshold voltage of the trigger which yields
a positive output rectangular waveform.  The time width of
that rectangular pulse is equal to the time width of the
input signal at the level of the trigger theshold voltage.
The threshold voltage of the Schmitt trigger has been designed
to be + 80 volts for all window channels.  Thus, small unwanted
droplets, such as fog, whose signal peak amplitude, plus the
15 volt D.C. reference, are below 80 volts, cannot trigger
the circuit, and, therefore, are not registered.

The rectangular positive pulses coming out of the
Schmitt triggers of two successive window channels are fed
into an "AND" gate, or coincidence circuit, which can yield
an output signal only if both input signals are present.
In Figure 2, window channels 1 and 2 feed the "AND" gate
No. 1 (V501) and window channels 2 and 3 feed the "AND" gate
No. 2 (V502), etc.  According to the principle of operation
of the sizing grid of gaps and windows as described in a pre-
vious section, the positive rectangular pulses from successive
window channels will coincide for a period of time, provided
that those pulses are generated by a droplet image large
enough to overlap both windows simultaneously.  Thus, "AND"
gate No. 1 yields signals for all droplets larger than gap
1, whereas "AND" gate No. 2 yields output signals only for
all droplets larger than gap 2.  Hence the number of the
drops that can yield an "AND" gate output decreases with

channel number until gate No. 13 is reached, which can yield
an output only for drops larger than the largest size gap
being used.

The output of the "AND" gates is a negative polarity
rectangular pulse which is fed to cathode follower stages.
The output of each cathode follower (V501) is matched to a
270 $\Omega$ transmission line that feeds information into the count-
ing and memory section of the rack unit. Figure 7 shows the
detailed circuit diagrams of the sensor chassis.

### III.2 Rack Assembly

The rack assembly, Figure 3, is composed of nine
chassis which house six major sections of the system;
namely, the counting-memory unit, the readout switches, the
recorder driving circuits, the clock-pulse unit and timer,
the power control unit, and the power supply unit.

### a) Counting-Memory

Part of Figure 2 shows the block diagram of the
counting memory unit which consists of thirteen identical
data handling channels. Each channel consists of four
cascaded decade counters, which are triggered by the
outputs of the pulse amplifier. Each channel pulse
amplifier (V601) is fed by the coincidence pulses from
the corresponding channel transmission line. For each
input pulse, the pulse amplifier generates a standardized

SIDE VIEW

TOP VIEW

REAR VIEW
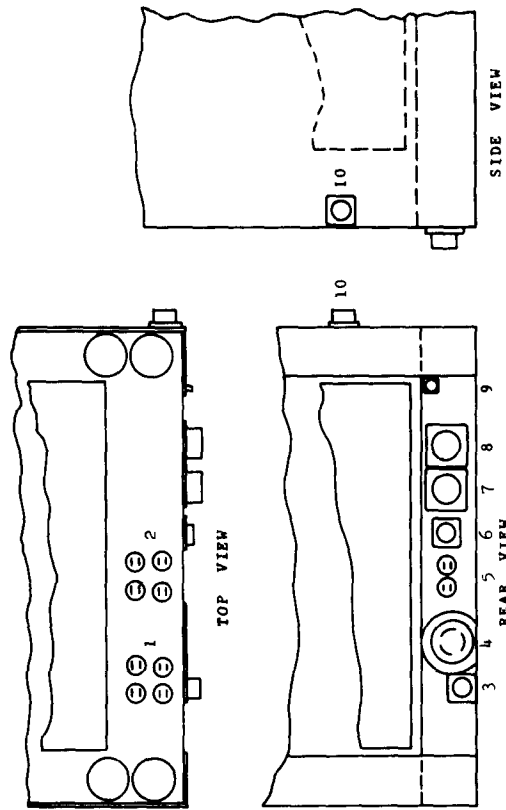
Section views of lower part of the rack

1. 110V line for regulated power supplies
2. 110V line for filament transformers
3. 250V regulated DC for sensor chassis and
   raindrop contact line for automatic operation
4. 110V - 30A power line input
5. 110V line for tape punch recorder and projector
6. Filament voltage for sensor chassis
7. Signal transmission lines socket (left)
8. Signal transmission lines socket (right)
9. Regulated high voltage outlet for photomultipliers
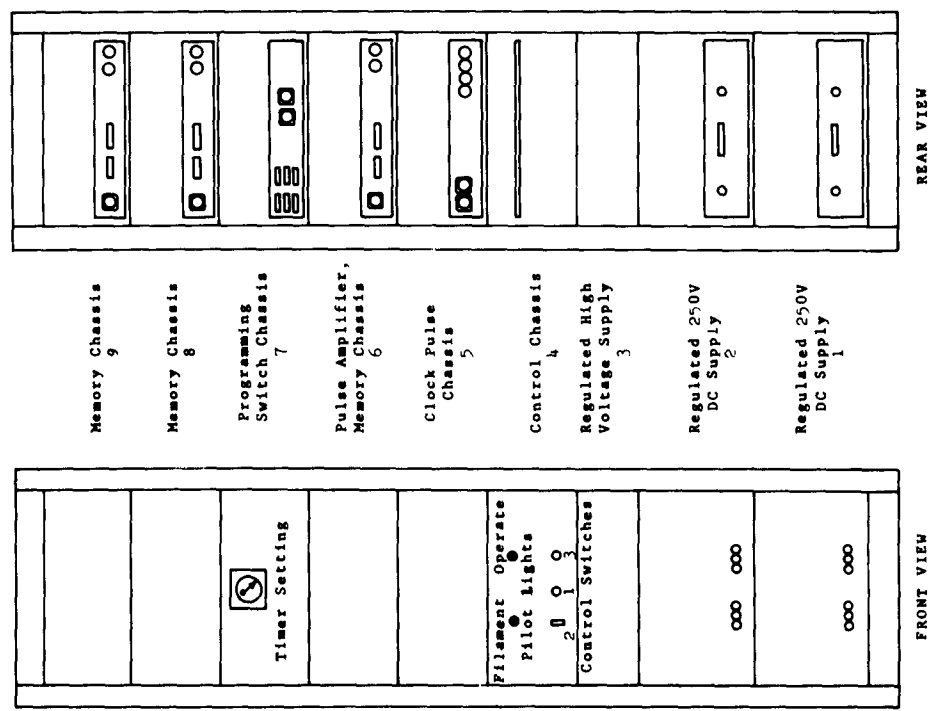10. Data output socket to tape punch recorder

Memory Chassis
9

Memory Chassis
8

Programming
Switch Chassis
7

Pulse Amplifier,
Memory Chassis
6

Clock Pulse
Chassis
5

Control Chassis
4

Regulated High
Voltage Supply
3

Regulated 250V
DC Supply
2

Regulated 250V
DC Supply
1

REAR VIEW

Timer Setting

Filament   Operate
Pilot Lights

Control Switches

FRONT VIEW

Figure 3.   RACK ASSEMBLY

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negative pulse with fast rise time and sufficient amplitude to reliably trigger the first binary of the first counter. Each counter requires ten input pulses to complete an entire counting cycle and since four of these counters are cascaded the last decade counter will complete its counting cycle when 10,000 pulses have triggered the first decade counter.

The total number of input pulses stored in any counter at any instant is read out as a change of voltage level at the four output terminals of the counter in the binary decimal code 1, 2, 2', 4. The presence of a count at a coded terminal is signaled by a level of approximately 115 V D.C. and its absence by 55 V D.C. The coded output of the first decade counters represents units; the second, tens; and the third and fourth counters, hundreds and thousands respectively. Figure 8 shows the circuit diagram of a decade counting unit which is a plug-in unit. The code output terminals of all decade counting units for all thirteen channels are connected in a special order to the contact points of the programming switch as is described in the programming switch section. Figures 9 and 10 show the memory chassis where the decade counters are mounted.

b) Programming and Readout Switch

The function of the programming switch is to collect the data stored in each channel and feed it into the punch tape recorder in a well organized manner. Since the counters

of each channel have a maximum storage capacity of 9,999,
with each decimal digit represented in binary coded form
(1, 2, 2', 4), it requires four rows of four columns apiece
to punch the data stored in each channel. For identification
of the channel on the tape record, a fifth row is used which
invariably shows the channel number, 1 to 14, in the same
binary decimal form used for data count. The tape actually
has five columns of space available, but the fifth column is
only used to punch a 10 when required for the identification
of channel 10 through 14.

The data is presented on the tape in sequential form.
Thus the four digit number stored in the channel 1 counters
is punched first, occupying four rows, and then the fifth
row is used for the channel number. Next, rows 6 through 9
present channel 2 data and row 10 the channel number '2",
and so on through 14 channels, whereupon a blank spacer of 3
rows separates the record from that of the next readout cycle
which repeats the format. It is therefore required that the
programming switch have a minimum of 5 x 14 = 70 point
contacts in at least 5 banks plus three more contacts for
the space between readouts, in order to be able to accommo-
date the whole format.

The programming switch is actually composed of three
electromechanical rotary stepping switches, Automatic Electric
Company, Type 45. Each stepping switch has 10 banks with

26 contact points per bank and separate wipers for each
bank. The three stepping switches are interconnected in
such a way that the wipers of the three switches are driven
sequentially, one after the other from the home position,
contact point "0", to contact point "25" by means of a
20 pps clock pulse voltage. As the wipers of the third
switch step from contact "25" to "0", both the first and
second switch are also stepped back to "0" or home position.

The clock pulse period is 50 milliseconds, and the
wipers dwell on each contact point for almost 48 milli-
seconds, and then transfer to the next contact in 2 milli-
seconds. Hence the total time for complete data readout
is 3.8 seconds. The 3.8 second readout scan is repeated
periodically at intervals determined by an automatically
resetting electric timer which may be manually preset for
any interval from five seconds to three minutes. Normally,
a one minute storage time is used.

Four of the ten banks of contacts are used to
connect the decade counter data outputs to the punch tape
recorder according to the following scheme: Wiper 10 = "1",
Wiper 9 = "2", Wiper 8 = "2'", Wiper 7 = "4". The first
four contacts of banks 7, 8, 9 and 10 on Programming Switch 1
are connected to the 16 data output terminals of the four
decade counters of channel No. 1. The fifth row of contacts
(in banks 7, 8, 9, 10) is used to punch the code identification

of channel No. 1, namely the number "1". Thus five rows of contacts and correspondingly, five data rows on the punch tape carry the total accumulated data count and a code identification number for each size channel. Channels 1 through 5 are accommodated on P.SW. 1, channels 6 through 10 on P.SW.2, and channels 11 through 14 on P.SW.3. The contacts of bank 6 of the Programming Switches carry the code weight of "10", which is only punched out on the tape when code identification numbers "10" through "14" are used to identify the last four data channels.

Thus wipers 6 - 10 of all three stepping switches feed data and numerical channel identification numbers in sequence into the tape punch recorder driving circuits. The tape record is read as follows: ones, tens, hundreds, thousands, channel No. 1; ones, tens, hundreds, thousands, channel No. 2; and so on through channel No. 14 whereupon a gap of three spaces marks the start of the next data print-out.

Other functions are carried out by the Programming Switches and their "Off Home" switches. Wiper 3 supplies the clutch magnet drive voltage to the punch tape recorder, and at the end of each readout cycle, wiper 5 actuates the reset relays of all the channel counters so as to empty them of stored data and ready them for a new data accumulation period. Also the "Off Home" switch of P.SW.1, a normally open

contact, actuates the four signal channel shorting relays
(R61 - 64) as soon as readout begins, and thereby grounds
out the terminal ends of the 14 data transmission lines
at the input to the signal pulse amplifiers in chassis
No. 6. In this way, the flow of data into the counters
is stopped during the readout period.

c)  Tape Punch Driving Stages

The block diagram of the tape recorder driving
stages is shown in Figure 4. The output terminals of the
programming switch are the data code wipers No. 6, 7, 8, 9,
and 10 as well as wiper No. 3, which supplies a 250 V D.C.
pulse train during the readout time by stepping around the
contact points of bank No. 3. This train of pulses
generated by the programming switch feeds the clutch
magnet of the tape punch which in turn cuts feed hole of
the tape allowing tape advance. Thus, the data code pulses,
if present, and the clutch magnet clock pulses are synchro-
nized.

The switch output wipers are D.C. coupled to
cathode followers (V71A, etc.) which are biased to cut off.
The code wipers feed the cathode follower at each step,
either a 115 Volts D.C. or a 55 Volts D.C. signal, depending
upon the presence or absence of information on the programming
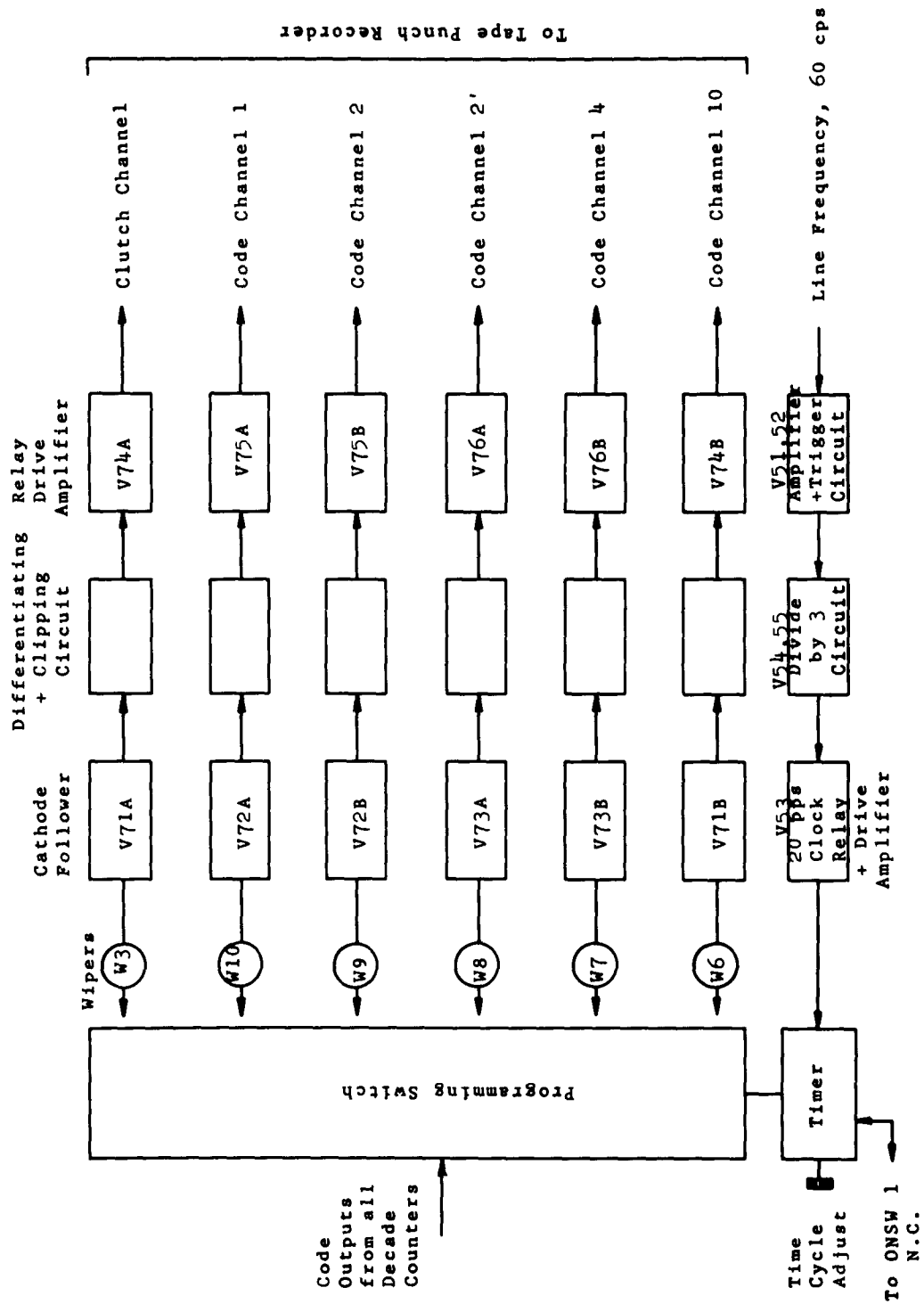switch points. The output of the cathode followers is a

Figure 4. BLOCK DIAGRAM OF PROGRAMMING SWITCH, CLOCK PULSE, and TAPE PUNCH RECORDER DRIVING STAGES

positive rectangular pulse which is differentiated by the
next stage. The negative pulse resulting from the differ-
entiating circuit is clipped and the positive pulse is
fed into the relay driving amplifier (V74A) which is biased
to cut-off. The pulses generated by the 115 Volts data
level have sufficient amplitude to bring the amplifier stage
out of cut-off and activate the relay, which drives that
particular channel of the tape punch. The pulses that are
generated by the 55 volts no-data level cannot bring the
amplifier stage out of cut-off and therefore no punch is
recorded on the tape. The differentiating circuit acts
to limit the duration of input pulses, $t_p$, to the tape
punch recorder so that $15 < t_p < 50$ milliseconds, a require-
ment for reliable operation of the Friden tape punch
recorder.

d) Clock Pulse Unit

The block diagram of the clock pulse generator
unit is shown in Figure 4. The 20 pps clock pulse that
drives the programming switch is derived from the 60 cps
line frequency. The line frequency voltage is amplified and
limited by V51 to produce a square wave with fast rise time.
The 60 cps square wave form is fed into the pulse amplifier,
V52, which generates a suitable pulse to trigger the divide-
by-three circuit consisting of two flip-flops, V54, V55,

- 25 -

with the necessary feedback. The divide-by-three circuit
feeds a 20 cps square waveform into a pulse amplifier,
V53, which causes the relay in the plate circuit to break
and make contact at the clock rate of 20 times per second.
This relay provides the clock pulse voltage that drives
the programming switch during the readout cycle.

e)  Power Control Chassis

    Figure 11 shows the wiring of the power control
chassis and Figure 3 shows the location of the power
control chassis on the rack assembly. There are three
front panel switches that control the operation of the
whole system. The first panel switch SW1 turns on the
light projector cooling blower and the motor of the Friden
tape punch recorder. SW2 turns on the projector lamp and
feeds line current to all filament transformers, bias
supplies and the rectifiers used for the programming switch
magnets and counter reset relays. A one minute filament
warm-up period is allowed by means of a thermal time delay
relay after which the dial light indicator marked "operate"
lights up. When the "operate" light is on, switch SW3 may
be thrown to the "ON' position, line current is supplied to
the high voltage transformers of the two regulated power
supplies, and to the high voltage transformer of the photo-
multiplier H.V. regulated supply, and the whole system starts

operation. On the "AUTOMATIC" position the system starts
and stops automatically with the beginning and end of the
rain. This is accomplished by means of an automatic rain-
drop sensor mounted outdoors on the light projector body.
The automatic rain sensor activates a sensitive relay when
it is wet by rain. The relay is series connected with the
power line and thus turns the system on and off

f)  Power Supplies

The two regulated power supplies made by Kepco pro-
vide 250 volts D.C. at 600 ma.   1000 volts for the photo-
multipliers is supplied by a regulated power supply made by
the Northeast Corporation.

IV   MECHANICAL DESCRIPTION (Drawing 10,000)

The mechanical-optical section of the unit is charged
with

1) Providing a high intensity source of illumination.
2) Confining the illumination to a desired test
   volume wherein uniform intensity is to exist.
3) Placing the test volume as far from splash effects
   as possible.
4) Imaging drops falling through the test volume upon
   a series of plastic windows separated by known gaps.
5) Conducting the light received from the window to a
   bank of photomultipliers with minimum loss.
6) Weatherproofing and structural support for all the
   above equipment.
7) Providing an automatic, rain actuated switch.

The design problems and details are presented below.
Frequent reference is made to drawing and part numbers. These
refer to the working drawings appended to this report.

## IV.1 Illumination (Drawing 12,000)

The source is a 750 watt projection lamp mounted in an especially built projector. The design is conventional, employing two condenser lenses, a reflector, a projection lens, and a blower mounted to a cast aluminum box.

Inspection of commercial projectors for this application, showed either poor collimating characteristics or unsuitable qualities for outdoor operation. In the final design, fair collimation is obtained by suitable lens choice, use of a sharp edged slide as a mask and careful positioning of the reflector with respect to the filament. The resulting beam is slightly divergent. Sharp edges are maintained through the test volume. Ratio of maximum to minimum intensity through the projector field is approximately 2.8 to 2.3. The lower intensity, existing at the sides, may affect the threshold locally, but because of the coincidence counting technique, does not affect basic accuracy.

Weatherproofing is obtained through use of non-corrosive components and careful ventilation design that permits forced air circulation but excludes rain. Dorade type ventilators are mounted on the top of the projector. Bulb replacement is accomplished by removing the entire side of the projector. Life tests indicate about 40 hours of usage. Possibly, more air flow may extend bulb life.
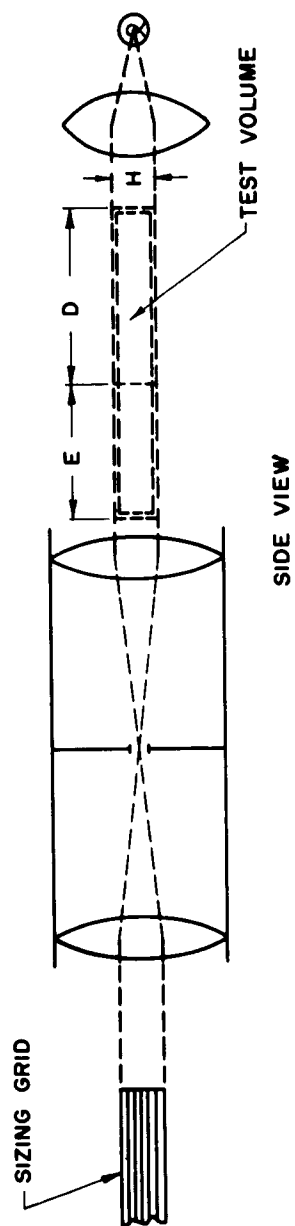
IV.2 **Test Volume**

The observed volume is in the form of a rhomboid.
Top and bottom faces are determined by the horizontal pro-
jection of the planes of the highest and lowest plastic
window contained in the grid out into the object space.
This determines dimension H (See Figure 5). The width, F,
of the volume is simply the projected width of the plastic
window. It should be as large as possible to produce a
large test volume, and yet not so large as to produce an
overlap situation, wherein more than one drop crosses any
window (horizontal plane) simultaneously. The depth, D, is
also to be large, subject to the probability of overlap,
limitations of depth of field (D + E) of the telecentric
lens combination and ability to produce constant intensity
across the projector field. The basic angle of inclination
of the projector output to the telecentric lens centerline
(scattering angle) is determined through considerations of
desired high image brightness (large forward scattering),
limited available depth of field of the telecentric lens,
and increasing edge effect error as the perimeter of the
test volume increases with respect to the volume (more partial
drops are registered).

Many of these considerations are antagonistic and so
the final test volume chosen is a matter of compromise.
Approximately 32.5 $cm^2$ of horizontal surface area forms the
top and bottom of the test volume, whose thickness is 1 cm.
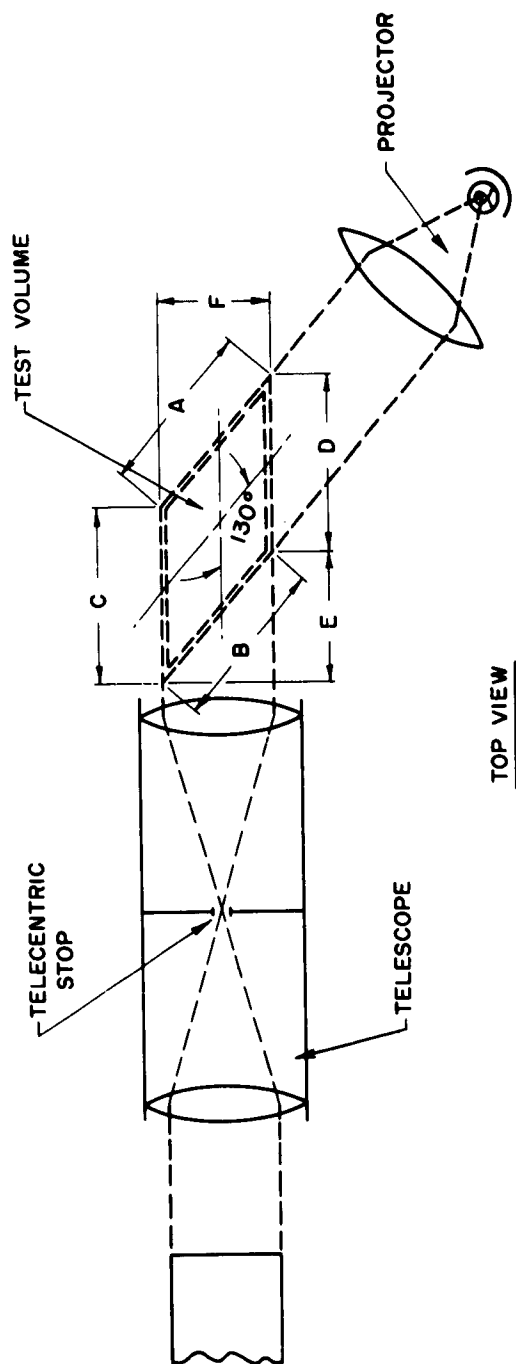
TEST VOLUME

FIGURE 5

TOP VIEW

SIDE VIEW

## IV.3  Splash and Interference

All edges of the sample volume are optically defined.
All structures and surfaces at or above the horizontal
level of the sample volume are physically remote from it.
A structural member (Part 10,009) passing a foot beneath
the sample volume is capped with a splash shield (Part 10,005)
to prevent rebound.

## IV.4  Imaging

All drops within the sample volume are imaged on the
sizing grid by the doubly telecentric lens combination,
referred to as lens barrel (Part 11,000).  It consists of
two plano-convex lenses (423 mm F.L., Achromatic, coated,
89 mm dia.) mounted symmetrically at one F.L. on either side
of a variable iris diaphragm.  For this optical system, unity
magnification is obtained for a distance between object and
image of four F.L. regardless of where the lens combination
is positioned.  Thus with the sizing grid close to the rear
lens, the distance from the front lens to the center of the
sample volume is almost two F.L., or approximately 82 cm.

The advantage of this doubly telecentric optical system
is that only rays close to being paraxial are accepted.  Thus
sunlight, or other ambient illumination which may tend to
light drops outside the sample volume is rendered ineffective,
for only drops within the projected width of the sizing
windows are seen.  In short, the optical angle of acceptance

for light rays is close to being zero degrees. The tele-
centric stop, an adjustable iris, also greatly increases
the depth of field when stopped down to a small enough
opening. The iris aperture is adjusted to a final position
which is a compromise between desired great depth of field
(small aperture) and desired high image brightness (large
aperture).

A light trap (Part 10,001) is mounted beyond the
test volume to serve as a black background against which
the drops are viewed. It consists of a simple hood lined
with optically black velvet.

The window stack consists of thin plastic window
elements separated by calibrated opaque spacers. The
front face of the stack is positioned at the focal plane
of the lens barrel.

IV.5  Light Pipes (Drawing 13,007)

The thin Lucite windows lead to individual photo-
multipliers (Drawing 13,000). Each is tapered from a width
of 5 cm at the stack end to a nominal 2 cm at the photomulti-
plier end, to accommodate the small photomultiplier cathode.
Each window is milled to a thickness of 0.010 inch at the
stack end to minimize stackheight, i.e., to enable the stack
to approach a plane and thereby minimize possible wind effects.
Many of the windows undergo considerable bending throughout
their path, however, tests of the light lost due to tapering

and bending indicated the attenuation to be but a few percent.

IV.6  Weatherproof and Structure

The basic structure is of welded steel. The lens barrel is mounted to the weldment through a steady-rest arrangement at each end of the barrel. A set of aluminum boxes (Part 13,000) house the phototube assembly which cantilevers off the lens barrel. A projector swivel (Part 10,009) ties the projector to the structure. A pivot permits variation of the scattering angle. The outboard leg of the swivel mounts a projector support stand (Part 10,012). Vernier adjustments of projector position may be obtained at the projector barrel support (Part 10,006) and the projector clamp ring (Part 10,010). The light trap (Part 10,001) is joined to the structure with a welded brace (Part 10,008). The frame (Part 10,002) is equipped with leveling screws.

Weatherproofing is gained partly by material choice. All adjustable or removable components are made of brass, aluminum or plastic. Steel is employed for basic structure only. All doors are equipped with neoprene rubber seal. All gaps are sealed with either epoxy resin or liquid neoprene. Two ventilation holes are drilled into the lens barrel underside to reduce condensation. A similar air flow path is placed in the photomultiplier assembly.

## IV.7 Automatic Rain Switch

The rain switch consists of two stainless steel plates separated by plastic shims. It is mounted on a hot area of the projector. As rain shorts the gap between the plates, a relay triggers the starting circuit and the entire system begins to operate. When rain stops, the projector heat will evaporate the shorting droplets, opening the circuit.

## V. CALIBRATION AND TEST

The calibration procedure for the Raindrop Spectrometer consisted in setting the gap sizes between windows to dimensions which will properly size all gaps. This was accomplished in the laboratory by generating artificial raindrops of various sizes and adjusting gaps so that an unambiguous go-no-go size indication was obtained for each size.

The nominal thresholds for each of the thirteen size intervals are in a geometric progression with a ratio of of 1.3. The size intervals are as follows (in millimeters):

Channel

| | | | |
|---|---|---|---|
| 1 | greater than | 0.2 | diameter |
| 2 | " " | 0.260 | " |
| 3 | " " | 0.338 | " |
| 4 | " " | 0.440 | " |
| 5 | " " | 0.571 | " |
| 6 | " " | 0.742 | " |
| 7 | " " | 0.964 | " |
| 8 | " " | 1.254 | " |

```
 9 greater than 1.630 diameter
10 "           "    2.120   '
11 "           "    2.757   "
12 '           "    3.580   "
13 "           "    4.650   '
```

(Channel 14 was used for recording the total rainfall as measured by a standard tipping bucket gage.)

Only a very limited series of tests of the completed Raindrop Spectrometer have been conducted to date. Once the calibration was completed, the consistency and repeatability of all size channels were checked by exposing the instrument to a stream of large uniform water droplets generated by a hypo- dermic needle dripping under a constant pressure head. The droplet stream was allowed to fall through the sample volume from a height of eight feet. Such a test should give a constant total count on all size channels up to that one which is the same or larger than the test drops. It is of course not a perfect test since some slight fluctuations in drop sizes might be expected and furthermore the limited fall distance of the test droplets resulted in shape oscillations of greater magnitude than would be expected with natural rain.

The results obtained from a series of three minute runs indicate that the counts were quite accurate and constant for channels 5 through 13. In one series a sharp cutoff was ob- tained at channel 11 and in another a sloping cutoff between channels 12 and 13. The standard deviation of the mean count

was in all cases less than 2 percent of the mean.

Some of the test data are tabulated below for illustrative purposes. As is evident from the table, the total number of drops counted in each channel from No. 5 to No. 11 was very consistent, while channels No. 3 and No. 4 gave slightly high counts. Cutoff was sharp at No. 11 since no drops were recorded on any run in channel No. 12. Channels No. 1 and No. 2 had to be ignored as they gave spuriously high counts for reasons which are discussed below.

| Run | Channels 3 —11 Mean Count | Standard Deviation of the Mean | Channels 5 — 11 Mean Count | Standard Deviation of the Mean |
|-----|-----|-----|-----|-----|
| 1 | 203 | 2.08 | 202 | 1.65 |
| 2 | 203 | 2.31 | 201 | 0.89 |
| 3 | 202 | 1.78 | 201 | 1.70 |
| 4 | 200 | 3.11 | 197 | 2.75 |
| 5 | 203 | 2.01 | 201 | 1.36 |
| 6 | 203 | 2.92 | 200 | 0.66 |
| 7 | 204 | 2.39 | 201 | 1.65 |
| 8 | 200 | 2.21 | 198 | 1.20 |

The difficulties experienced with the first four channels, the small size channels, are due to excessive sensitivity. Although these channels did measure and count small drops accurately during laboratory tests and calibrations, they tended to give erroneously high counts when large drops were being observed. The cause of this error is well understood and engineering modifications were planned to cure it, but time and money were not

available for any further work.

Field testing of the Raindrop Spectrometer was curtailed because of the problem with the smallest size channels and at the present time the planned modifications are being incorporated into the instrument. A thorough discussion of these modifications is included below:

## VI.  DISCUSSION AND RECOMMENDATIONS

Testing and operating experience with the Raindrop Spectrometer has been insufficient to permit final evaluation of its performance and reliability. To date, a limited amount of field operation has demonstrated the feasibility and practicality of the device. Apart from a few minor "bugs" in some of the components, the only major problem which has arisen is the difficulty with the first few channels mentioned above.

The spurious excess counts recorded by channels No. 1 through 4 result from the following causes:

The sample volume is optically defined by the intersection in space of the projection of the sizing grid (rectangular in shape) and a collimated light beam of rectangular cross-section. Thus all drops falling through the sample region are illuminated from the side by the collimated light beam. Their images appear on the sizing grid as bright crescents which have an apparent height of less than one-half

the true drop diameter. In other words, because of the side-
lighting, the drop images are not full circles as had been
obtained in earlier tests with backlighting. The apparent
size of the images is still linearly related to true drop
size, and, therefore, calibration was still accurate. But
the electrical signals generated by the photomultiplier tubes
which view these crescent images are smaller in amplitude
than would be obtained with a fully illuminated drop. Further-
more, the electrical pulses generated have much less steep
leading and trailing edges.

A theoretical analysis of this situation has shown
that the pulse amplitude generated by a backlighted drop
crossing a window can be as much as 12 times greater than
that of an identical sidelighted drop. This conclusion is
borne out by the observation that 200 micron drops now pro-
duce pulses of 1 volt peak from the photomultiplier whereas
with backlighting such as was used for earlier tests, 10 volt
pulses were obtained. In addition, the analysis revealed an
improvement in the steepness of the pulse edges of approxi-
mately 10 to 1 for backlighting as compared to sidelighting.

Larger drops produce a much greater pulse amplitude
than 200 micron drops, typically 50 volts as compared to
1 volt. In the first four channels, all signals must be
greatly amplified in order that even a 1 volt pulse will
trigger the Schmitt trigger circuit and thereby generate a

standardized rectangular pulse related to signal pulse du-
ration. As a result of these factors, when a large drop
image crosses the window of one of the first four channels,
the shallow sloping leading and trailing wings of its signal
pulse are as high in voltage as the peak of the whole pulse
generated by a small drop. There is some noisiness on the
pulse wings. As a consequence, the Schmitt trigger tends
to fire in response to the noise spikes and excess spurious
counts are recorded. These effects have all been observed
on a scope. The spurious count difficulty does not arise
after channel 4 because lower gain amplifiers are used in
the higher numbered channels where only large amplitude pulses
have to be counted.

It is felt that this difficulty can be readily cured
by means of planned engineering modifications. Rather than
use a collimated light beam to define the sample volume, in
the alternate technique planned, the sample volume would be
optically defined by the right angle intersection of two
projected images of the rectangular sizing grid. This can
be accomplished by an optical beam splitter (half-silvered
mirror) immediately in front of the telescope's objective lens,
and two additional full-silvered mirrors to redirect the two
images, as shown on Figure 6. The effect is that any drop
within the intersection volume would form two images on the
sizing grid windows - one along each optical path. By means

TOP VIEW
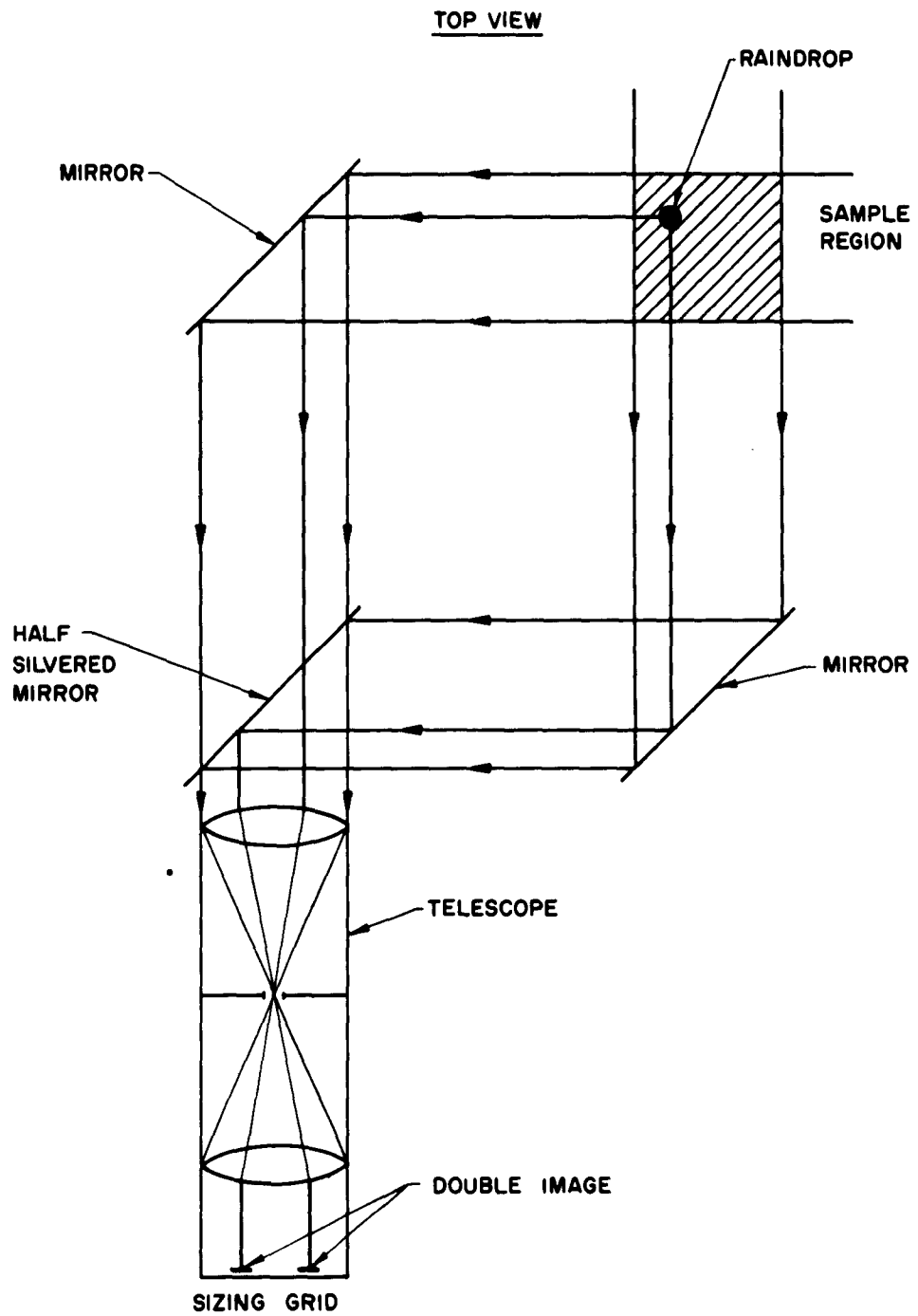


FIGURE 6

of polarization filters or color filters, alternate windows can be made to "see" only one of the two images. Thus only when a drop is actually within the sample volume will coincidences be detectible.

This scheme offers many advantages: First, it will result in a more sharply defined sample volume with a higher ratio of area to perimeter so as to minimize edge effects. Second, since collimated sidelighting is no longer required for sample volume definition, ordinary floodlighting can be used to achieve full size, brighter drop images. This will result in larger amplitude, steeper signal pulses and thereby insure that the difficulty with spurious counts on channels 1 to 4 can be circumvented. In fact, it is planned to clip off the bottom of all signal pulses when larger amplitudes have been obtained, and this will completely avoid the problem of low level noise.

On the basis of the limited operational experience to date, some recommendations for tests and modifications are listed below.

1) Test performance with fully illuminated drops (backlighting), rather than the present sidelighting, to get larger signal levels so that channels 1 to 4 can operate accurately. This will involve some modifications of the signal amplifiers so as to clip off the low level portions of all signal pulses and thus avoid any noise effects.

2)  If the backlighting technique proves successful,
construct beam-splitting optics so as to incorporate
the two-view technique described above.

3)  Recalibrate the gap sizes between sizing grid
windows.  With backlighting, the gaps will have to
be enlarged to true drop size, and calibration will
be easier and more accurate.

4)  Extensive laboratory and field tests should be
conducted to prove out the instrument and gain opera-
tional experience.

## VII. CONCLUSIONS

Although it is too early to finally evaluate the
worth of the Raindrop Spectrometer for field use, some
conclusions may be drawn concerning its capabilities and
performance.  The drop sizing and counting technique used
in this instrument is felt to have been proven sound.
The novel principle employed, the go-no go sizing grid
has been shown to offer unique advantages in speed, accu-
racy, and efficiency.  The number of drops which can be
observed, sized and recorded per unit time is orders of
magnitude greater than what has been achieved heretofore.
Furthermore, the instrument itself, even in its present
prototype embodiment, has proven quite reliable.  It is
therefore strongly urged that the recommended modifications

and improvements be completed and the device be given

extensive field tests. During such field tests, a great

deal of data on raindrop size spectra would be accumulated;

perhaps of much greater quality and quantity than all pre-

viously published data.
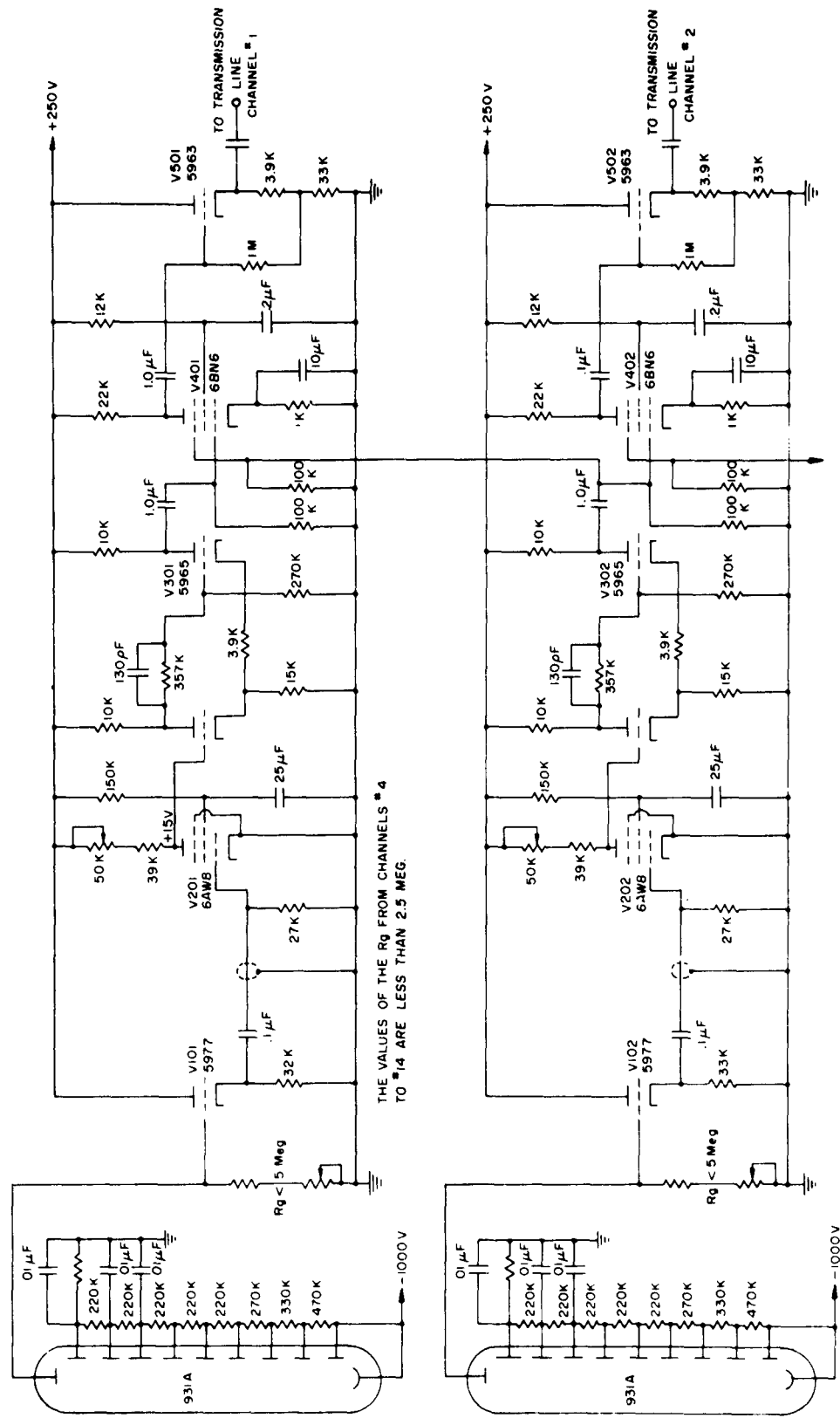
FIGURE · CIRCUIT DIAGRAM OF SENSOR CHASSIS, CHANNELS #1 AND #2
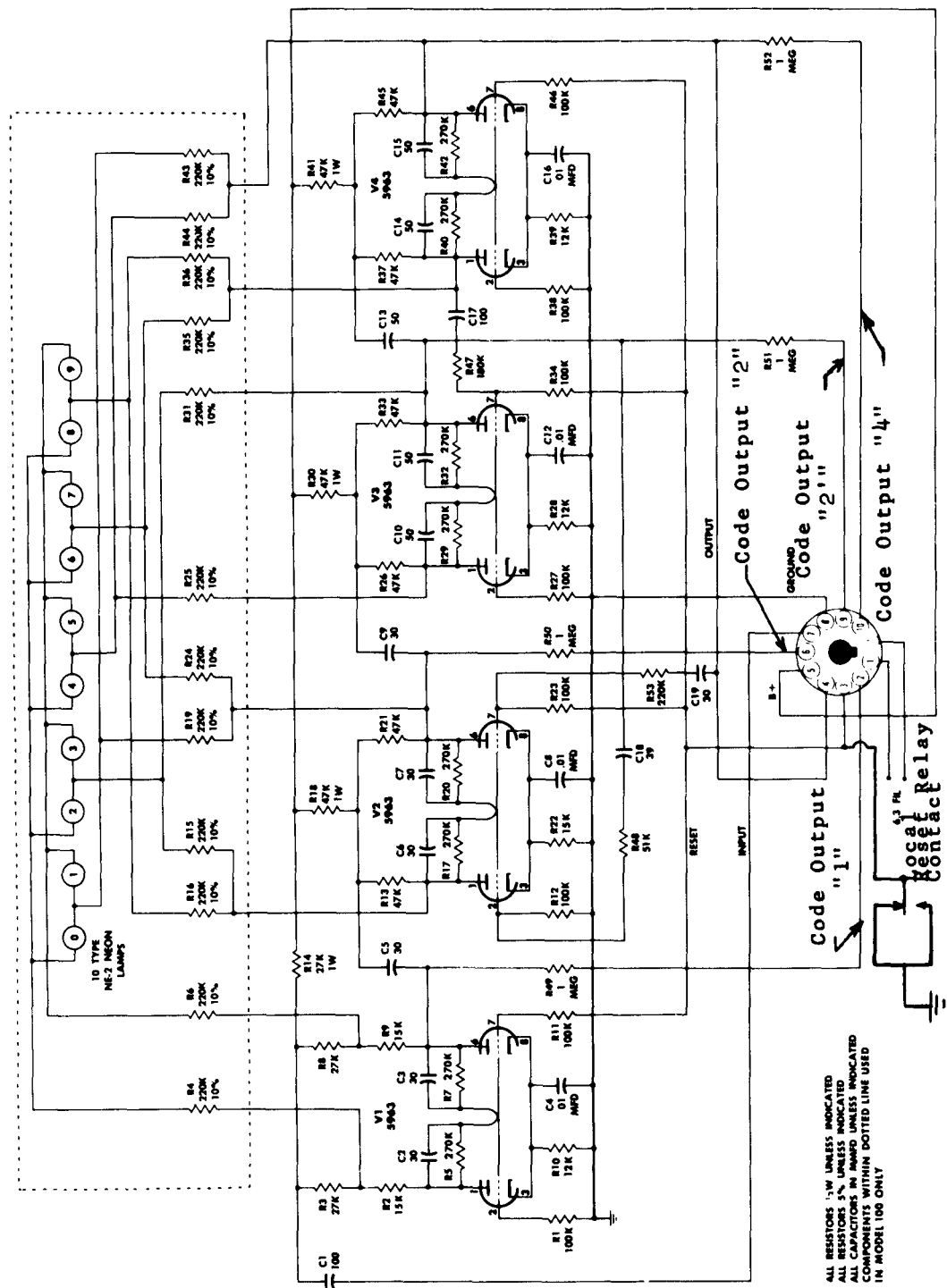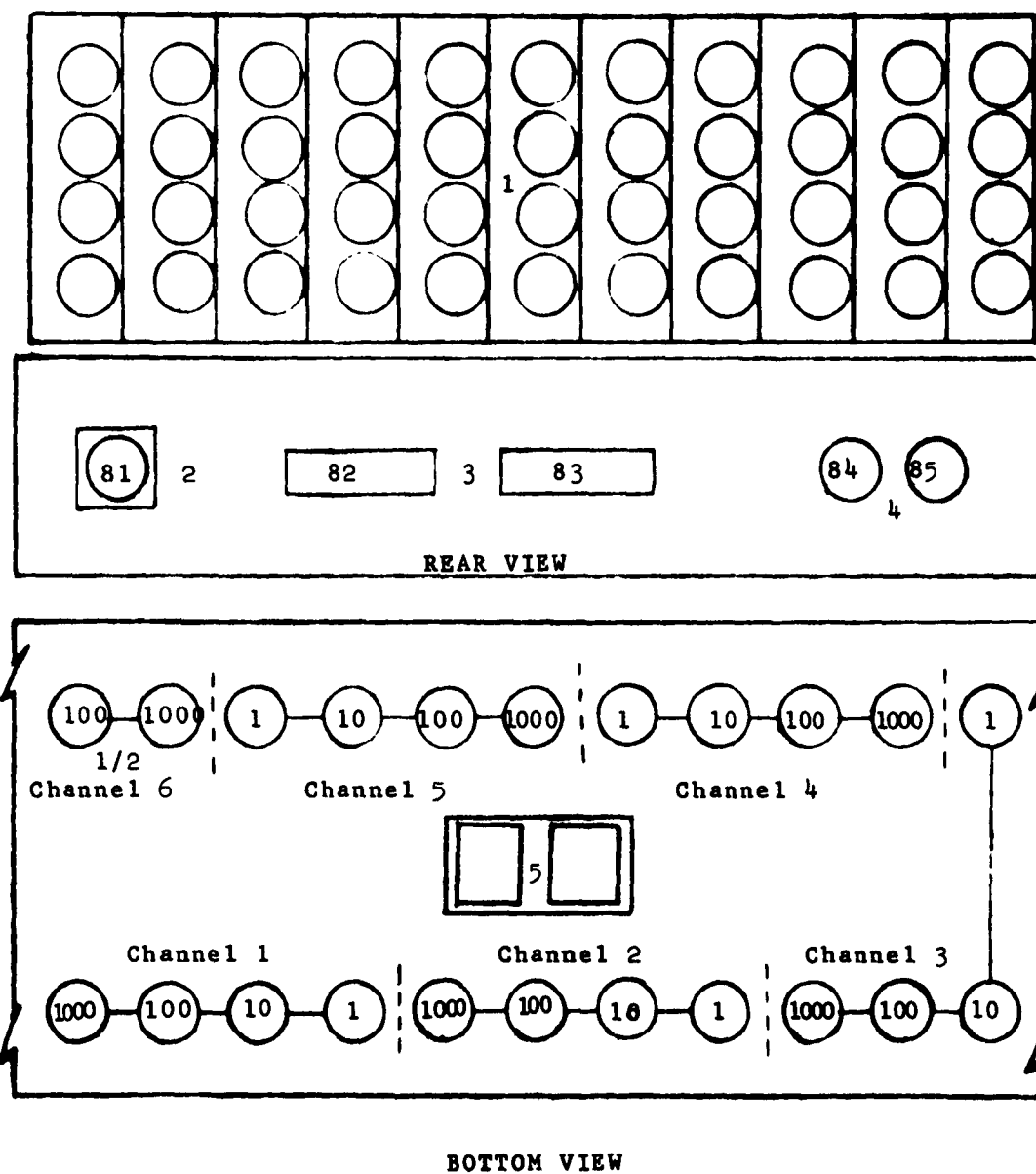
THE VALUES OF THE Rg FROM CHANNELS #4
TO #14 ARE LESS THAN 2.5 MEG.

ALL RESISTORS ½W UNLESS INDICATED
ALL RESISTORS 5% UNLESS INDICATED
ALL CAPACITORS IN MMFD UNLESS INDICATED
COMPONENTS WITHIN DOTTED LINE USED
IN MODEL 100 ONLY

Figure 8.  MODEL 105C DECADE COUNTING UNIT (Computer Measurements Co.)

BOTTOM VIEW

1. Memory Counters
2. Signal Input Socket
3. Code Output Sockets
4. Filament Sockets
5. Reset Relays

Figure 9.  MEMORY CHASSIS No. 8
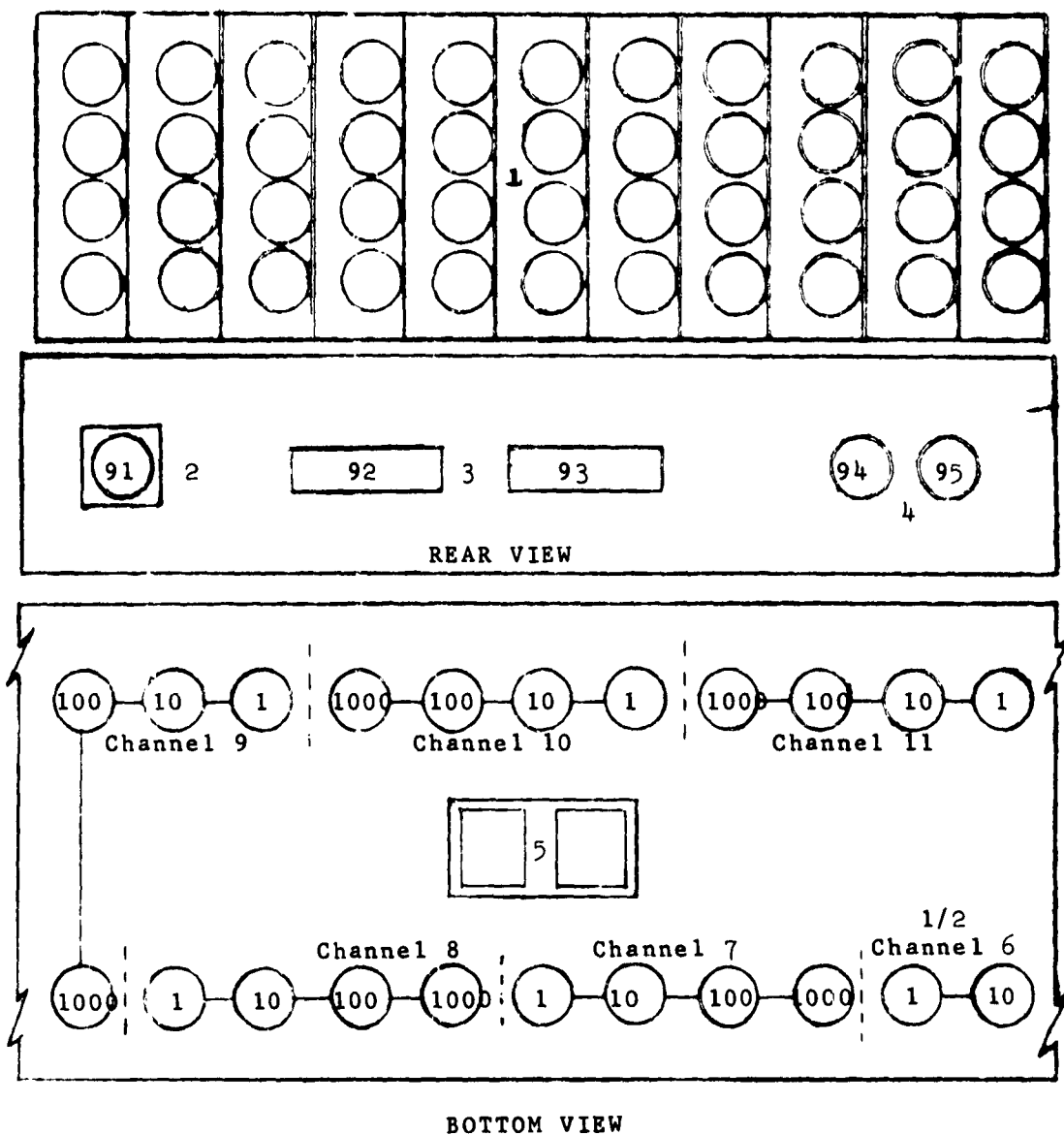
REAR VIEW

BOTTOM VIEW

1. Memory Counters
2. Signal Input Socket
3. Code Output Sockets
4. Filament Sockets
5. Reset Relays

Figure 10.  MEMORY CHASSIS No. 9

Figure 11. POWER CONTROL CHASSIS No. 4 – WIRING DIAGRAM

| PART NO | PART NAME | QUAN | DWG NO | MATERIAL |
|---|---|---|---|---|
| 10,001 | LIGHT BAFFLE | 1 | 10,001 | ALUMINUM |
| 10,002 | ASSEMBLY FRAME | 1 | 10,002 | STEEL |
| 10,003 | LENS BAR. CLAMP RING | 2 | 10,003 | ALUMINUM |
| 10,004 | CLAMP KNOB | 9 | 10,004 | ALUMINUM |
| 10,005 | ANTI-SPLITTER STUD | 1 | 10,005 | BRASS |
| 10,006 | PROJECTOR BARREL SUP | 1 | 10,006 | ALUMINUM |
| 10,007 | 8-24 CAP SCREW x 2¼ | 2 | — | STAINLESS STEEL |
| 10,008 | LIGHT BAFFLE BRACKET | 1 | 10,008 | STEEL |
| 10,009 | PROJECTOR SWIVEL | 1 | 10,009 | STEEL |
| 10,010 | PROJECTOR CLAMP RING | 1 | 10,010 | ALUMINUM |
| 10,011 | LIGHT BAFFLE SUPPORT | 1 | 10,011 | STEEL ANGLE |
| 10,012 | PROJECTOR SUP STAND | 1 | 10,012 | AS NOTED |
| 10,013 | 10-24 R.H. SCREWS x ½ L | 4 | — | STAINLESS STEEL |
| 10,014 | HEX MACHINE BOLT x 5½ L | 1 | — | STAINLESS STEEL |
| 18,000 | PHOTO TUBE ASS. | 1 | 8,000 | — |
| 12,000 | PROJECTOR ASS. | 1 | 12,000 | — |
| 11,000 | LENS BARREL ASS. | 1 | 11,000 | — |

RAIN DROP SIZER & COUNTER

| PART No | PART NAME | QUAN | Dwg No | MATERIAL |
|---|---|---|---|---|
| 12,014 | RAIN SWITCH (LEFT SIDE) | 1 | 12,014 | STAINLESS STEEL |
| 12,015 | RAIN SWITCH (RT. SIDE) | 1 | 12,015 | STAINLESS STEEL |
| 12,016 | PROJECTOR COVER | 1 | 12,016 | 24 ST ALUM |
| 12,017 | STUD | 4 | 12,017 | 24 ST ALUM |
| 12,018 | COVER CLAMPING KNOB | 4 | 12,018 | 24 ST. ALUM |
| 12,019 | PROJECTOR BODY | 1 | 12,019 | ALUM CAST |

| PART No | PART NAME | QUAN | Dwg No | MATERIAL |
|---|---|---|---|---|
| 12,001 | VENT COVER SUPPORT | 2 | 12,001 | 24 ST ALUM |
| 12,002 | VENT TUBES | 4 | 12,002 | 24 ST. ALUM |
| 12,003 | VENT COVER | 1 | 12,003 | 61 ST ALUM |
| 12,004 | 8-32 RD.HD x ½ LONG | 2 | — | BRASS |
| 12,005 | 37½ vPm.a DOB 750 w. BULB | 1 | 12,005 | — |
| 12,006 | BULB SHIELD | 1 | 12,006 | 24 ST ALUM |
| 12,007 | LAMP SOCKET SUPPORT | 1 | 12,007 | 24 ST ALUM |
| 12,008 | PROJECTOR SUPPORT | 1 | 12,008 | 24 ST ALUM |
| 12,009 | BLOWER | 1 | 12,009 | — |
| 12,010 | 8-32 RD. HD X ½ LONG | 2 | — | BRASS |
| 12,011 | 10-32 FL.HD x ½ LONG | 3 | — | BRASS |
| 12,012 | 10-32 RD.HD ½ LONG | 6 | — | BRASS |
| 12,013 | 8-32 RD.HD. ½ LONG | 8 | — | BRASS |
| 12,100 | PROJECTOR LENS ASS'BLY | 1 | 12,100 | — |
| 12,200 | CONDENSER ASS'BLY | 1 | 12,200 | — |
| 12,300 | REFLECTOR ASS'BLY | 1 | 12,300 | — |
| 12,400 | LENS BARREL CLAMP | 1 | 12,400 | — |

PROJECTOR ASSEMBLY

HALF SIZE

NEXT ASSY 10,000 7D

12,000

DRAWING PART NUMBER

BLOWER

NOTE:
POLISH ALL SIDES TO HIGH
TRANSPARENT FINISH, ALL
CORNERS & SIDES SHOULD
BE SQUARE

15"

3"

PLEXIGLAS

| MATERIALS | PLEXIGLAS | | | 1ξ | 13.000 | 7D |
|---|---|---|---|---|---|---|
| SPEC. | | SCALE FULL SIZE | | No. REQ. | NEXT ASSY | FINL. |
| FINISH | | LIMITS | | DRAWN | DATE | APPRD. |

WINDOW

PART NAME

NEW YORK UNIVERSITY
RESEARCH DIVISION
UNIVERSITY HEIGHTS
NEW YORK 53, NEW YORK

| B | 13.007 |
|---|---|
| DWG. SIZE | DRAWING PART NUMBER |
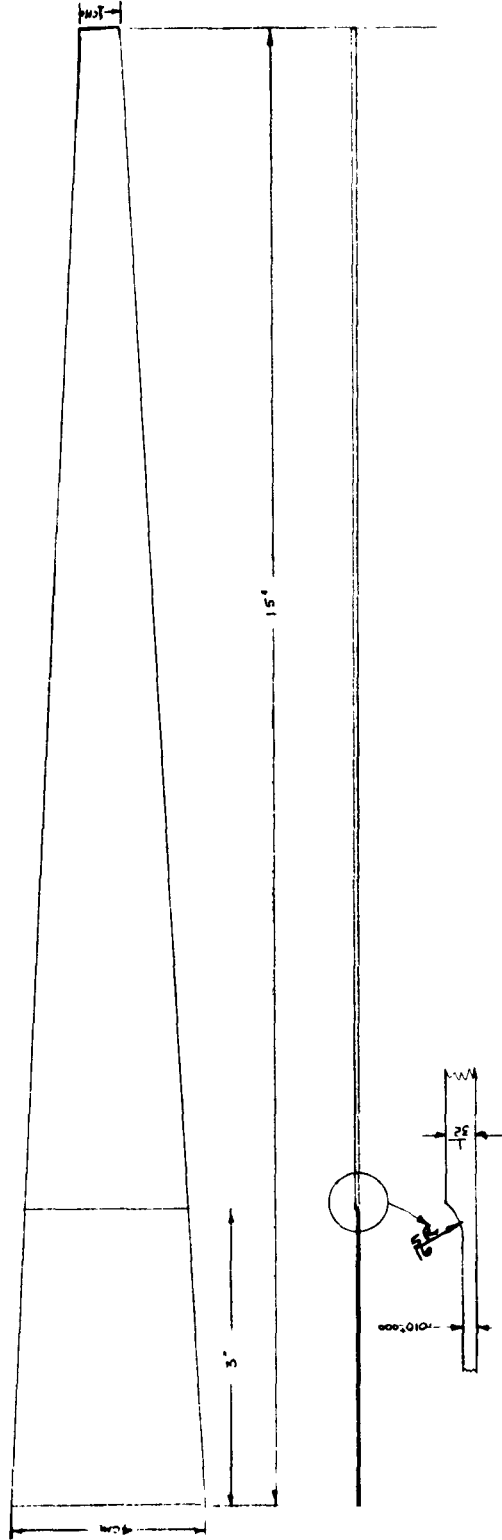
UNLESS OTHERWISE NOTED ALL DIM. IN
INCHES WITH TOL. OF : FRAC. ± 1/64
DEC ± .001 ; ANG ± 1/2°

PHOTOTUBE ASSEMBLY

PART NUM

| NEW YORK ... ... | D | 13,000 |
| RESEARCH ... | | |
| UNIVERS ... T | DWG SIZE | DRAWING PART NUMBER |
| NEW YORK 5 ... YORK | | |

SHEET 1 OF 2
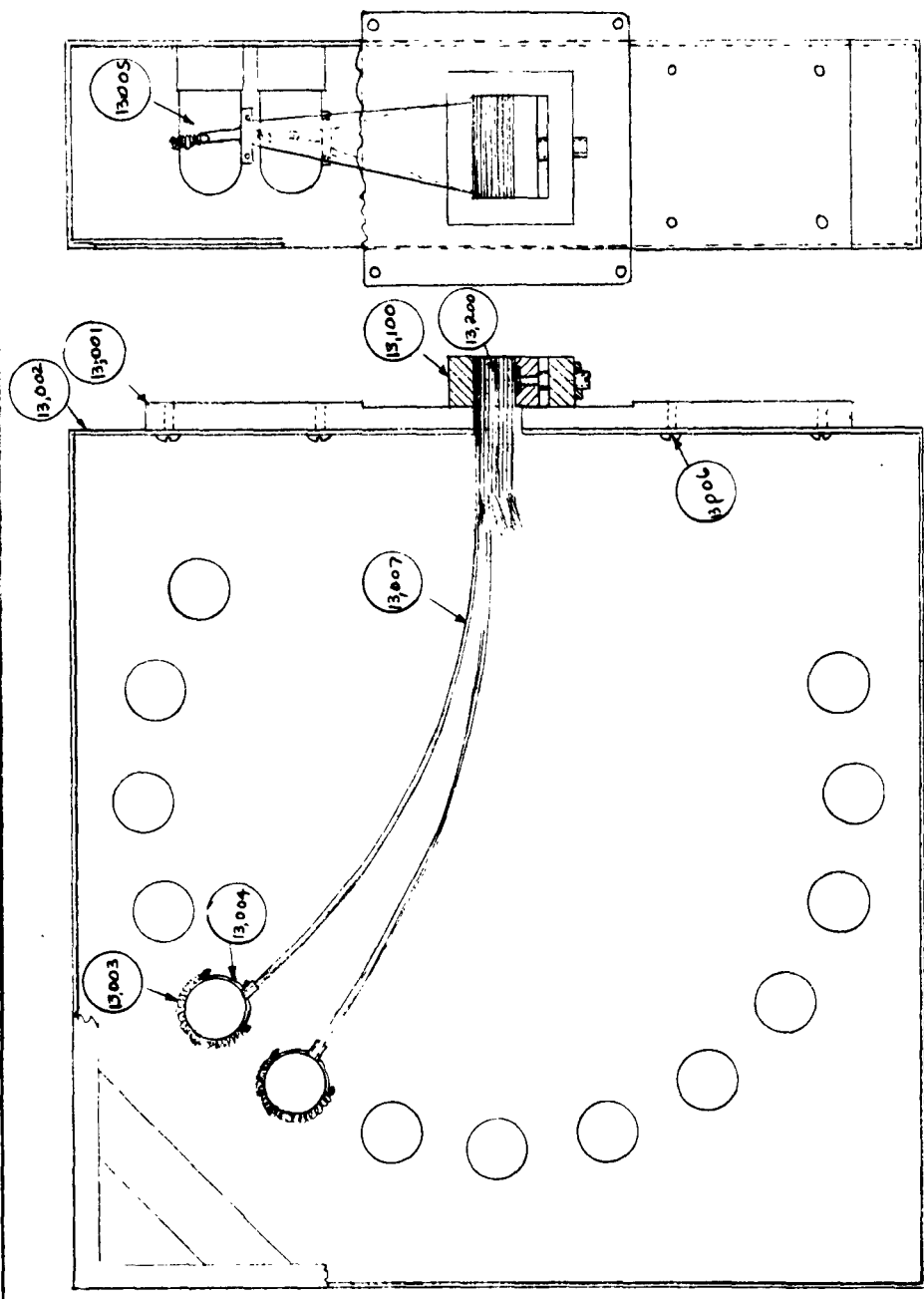
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GROUND BASED RAINDROP SPECTROMETER
Final Report    Feb. 62
by Alan M. Nathan, Leon Bennett, and C. J. Makris
15 Apr. 63, 43 p. illus.    Report No. 788
Contract No. DA36-039-SC 84970    Unclassified Report

DESCRIPTORS:  (Meteorology, Raindrop, Particle Size, Meter, Recording System.)

Identifiers:  Raindrop size spectra, sizing and counting of raindrops.

A novel ground-based Raindrop Spectrometer is described and its operating principles explained.  The instrument is designed to count and size automatically all raindrops falling freely through an optically defined sampling area of 32 cm². All drops larger than 0.2 mm in diameter are counted and assigned to the appropriate one of 13 size intervals, the last interval being drops larger than 4.6 mm.

The running total count of drops in each size interval is accumulated in an electronic memory for a time interval which can be preset to any duration from 5 seconds to 3 minutes.  Then the stored counts are read out automatically and recorded on a paper tape punch in seconds, after which the memory clears and data accumulation begins again.  The instrument can store up to 10,000 counts in each of the thirteen size intervals during each data collection period.  From the record, the following information can be derived:  raindrop size spectra as a function of time, average volume drop radius, total rainfall or rainfall rate.